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by

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A.P.I. prevention & control of oil spills joint conf. Proceedings.

Washington, D.C., June 15-17/71.

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OIL SPILLED WITH ICE: SOME QUALITATIVE ASPECTS

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ABSTRACT

The note gives an indication of the ways in which containment by an ice cover of spilled oil can occur and of some of the ways in which the containment may be utilized in cleanup. There is in the experience the implication that certain characteristics of an ice cover may be usefully simulated in a man-made structure.

If spilled oil is to be removed from a water surface, i.e., picked up or burned, it must first be contained. If this is not achieved by a shore and by the material on a shore, e.g., by debris, weed or ice, then it is frequently not possible to provide containment by the deployment of man-made structures. In the following it will be suggested that an ice cover can limit oil movement at the surface almost as well as a shore and that perhaps certain features of an ice cover could be incorporated into the techniques of boom construction and deployment. It is emphasized that the experience is largely qualitative, so that while a clear indication of processes is not possible, several are suggested. Of course an operational association with oil spills usually does not provide adequate opportunity to obtain anything but qualitative data; however, it is believed that the considerations described here could be examined through experiment, perhaps of the type described by Vance[1].

The general conclusion about the effectiveness of an ice cover was derived in part from an experience on the east coast of Canada in late winter[2] and from two in summer in the Canadian Arctic[3,4]. In each, the containment by the ice was such as to limit the extent of shoreline eventually contaminated and in one, the containment allowed time for the consideration of a number of recovery and cleanup methods which included pumping on to the sea ice to facilitate evaporation. It is clear, however, that we are not yet able to exploit containment on every occasion it might occur. As ice can provide unusually effective containment, methods of such exploitation in the arctic and other ice covered waters might be pursued. This would include the consideration that the containment by ice can occur for oil on a water surface, on the ice surface, and perhaps under the ice surface, and within the structure of the ice.

Particular Oil in Ice

Bunker C from the tanker ARROW aground in Chedabucto Bay was found as particles within the structure of the ice (Figure 1a); a form of oil which was very reminiscent of the oil seen in seawater samples obtained there at depth.[5] Apparently, the oil particles were at the surface and became contained in the ice during the process of freezing. Later, when ice was melting it was possible to discern areas of "dirty" ice, at least 50 feet in diameter, within which were near-surface accumulations of oil 2-6 inches in diameter (Figure 1b). At this time I was able to view samples of the ice and oil and I considered that the pattern resulted from a redistribution of the particulate oil due to internal movement with melt water (the ice cover was 4" thick and had been 8" thick), but this is not at all certain. Neither is it certain by what process the oil particles were formed. Forrester[5] suggested that wave action on oil at the water surface and on oil ashore could lead to the formation of particles; Wicks[6] has shown that "showers of droplets" can occur at the head wave region of oil containment. It seems likely that both processes occurred at Chedabucto.

Oil on the Water Surface with Ice

In particular, large accumulations of oil were contained across ice barriers there (Figure 1c) which could have led to the oil droplets of Wicks and hence the particles. Oil had become incorporated into the ice sheet during growth and ice can be seen mixed into the accumulations of oil at the leading edge. Although an entirely adequate survey method was not developed, we did attempt to determine the amount of oil contained. On some occasions the oil was judged to be 2-4 inches thick, but generally it appeared to be less than an inch. At the time there was no way by which we could pick up the Bunker C so contained; neither did we learn how to burn it. Even now I am not certain

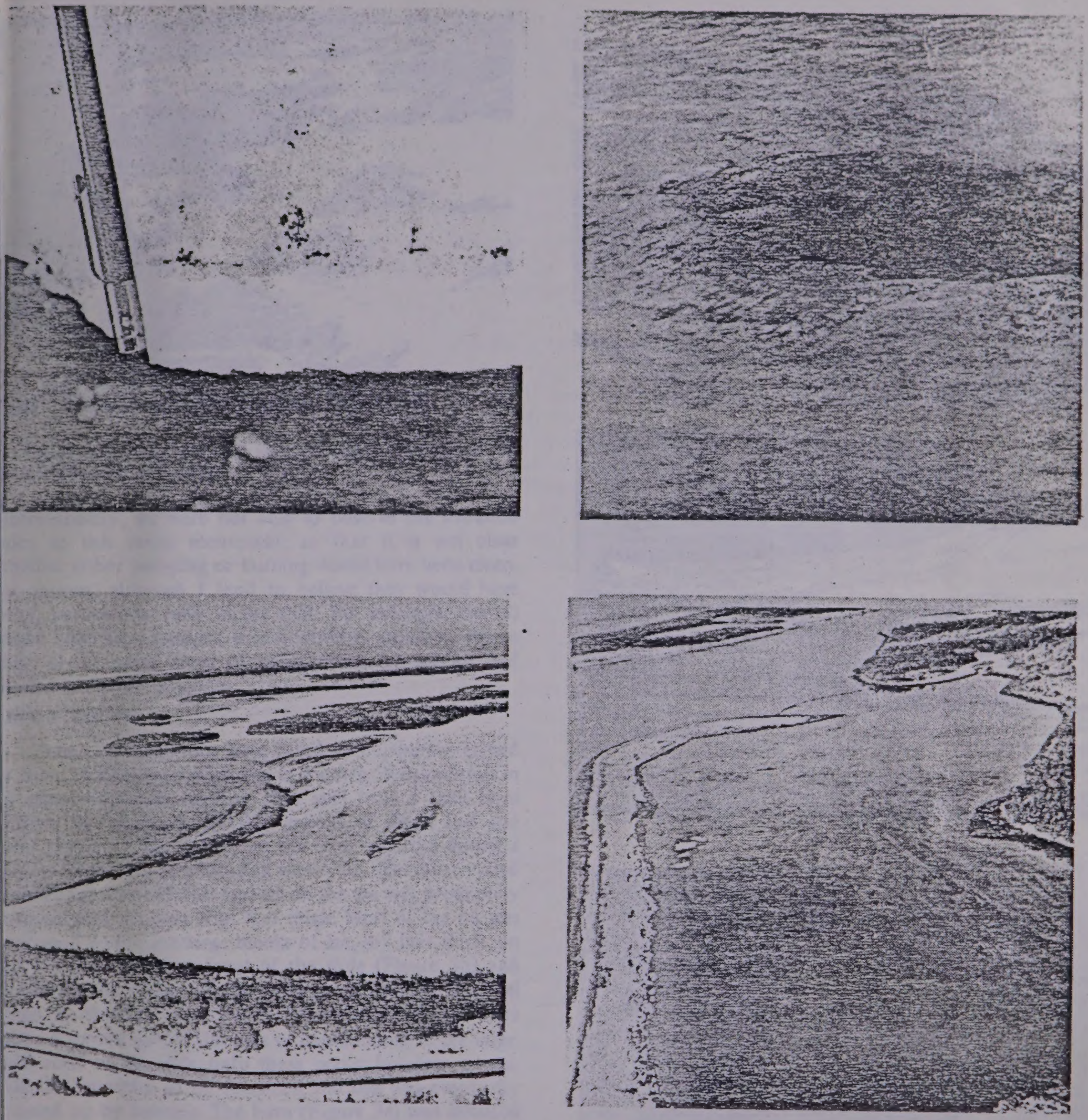

Figure 1: Four photos, the last three from a helicopter on ırch 21, 1970, of oil and ice in Chedabucto Bay[2]. (a) Oil in rticulate form in a sample of ice from the relatively new ice cover Lennox Passage on February 28. View is of a vertical section; the ıser end of the pencil is at the under-side of the ice. (b) The ice surface toward the eastern edge of the ice cover in Lennox Passage. (c) View to the north of Haddock Harbour. (d) View of Janvrin Lagoon in which the last of the ice and oil there and the boom at the entrance may be seen.

ıw best this containment might have been exploited, al- ough pickup machinery of the type developed by Sewell[2] ɔuld likely have been effective.

Containment by ice occurred at Resolute, N.W.T. ɔout 75° N latitude) in August, 1970 when a spill[4] oc- rred into the harbour where an 8-9 tenths ice cover isted. The spill was relatively small, perhaps 3000 gallons, and was of a relatively light fuel oil, heavier than diesel but much lighter[7] than a Bunker C type. For about six days after the spill occurred, the ice containing the oil was confined to the head of the harbour by the southerly wind. Subsequently the wind changed to the north and moved much of the ice and oil out of the harbour, although by this time a portion of the shore had been oiled (Figure 2).

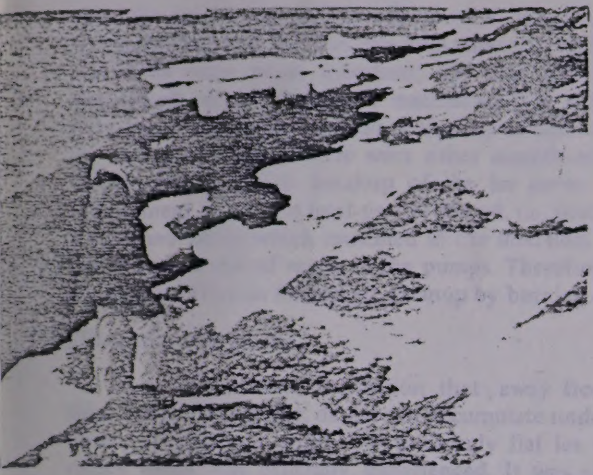

Figure 2: Ice grounded on a relatively heavily-oiled portion of ie intertidal zone at Resolute.

Jnfortunately, we were not able to observe the situation rior to this major movement, so that it is not clear 'hether either pumping or burning would have been clean-p options, although I tend to believe they would have een, particularly early in the spill. For example, the oil iight have been pumped into containers ashore or into a iip, or to other areas of containment by sea ice and urned in discrete amounts.

)il on Sea Ice

These considerations were based on experience gained ı June, 1970 at Deception Bay in western Hudson Strait in ı association with cleanup of a spill from a tank farm Figure 3a) of about 400,000 gallons of diesel fuel and ›me gasoline.[3] The spill from the farm occurred during a me of small tide at a location where the tidal range varied om about 12 to 19 feet and where the sea was completely overed with ice over four feet thick. Most of the oil was ontained within the large blocks of ice, 4-7 feet thick, on ıe intertidal zone in front of the slide (Figure 3b) and earby on the surface of the water in pools along the tidal inge. As the tidal range increased to a maximum (on June 2), oil moved out of the area of containment in the inter-dal zone of the slide onto these pools; however, a con-derable quantity of oil remained and this was eventually eaned up by burning. The burn (Figure 3c) was initiated : low water at the time of maximum tidal range. It fol-›wed a general cleanup of the site during the previous 'eek. The cleanups was initiated by pumping onto the sea e surface where it was eventually burned. The com-ination proved an appropriate method of cleanup although ıe burning caused some air pollution and some biological amage resulted[8].

The significant aspects of the incident are that the ice over provided effective control of the spill over a period of vo to three weeks and furnished an effective platform om which to work. It also provided a unique type of ›ntainment, i.e.,on the ice surface, as a secondary step in eanup. The considerations which led to pumping the oil

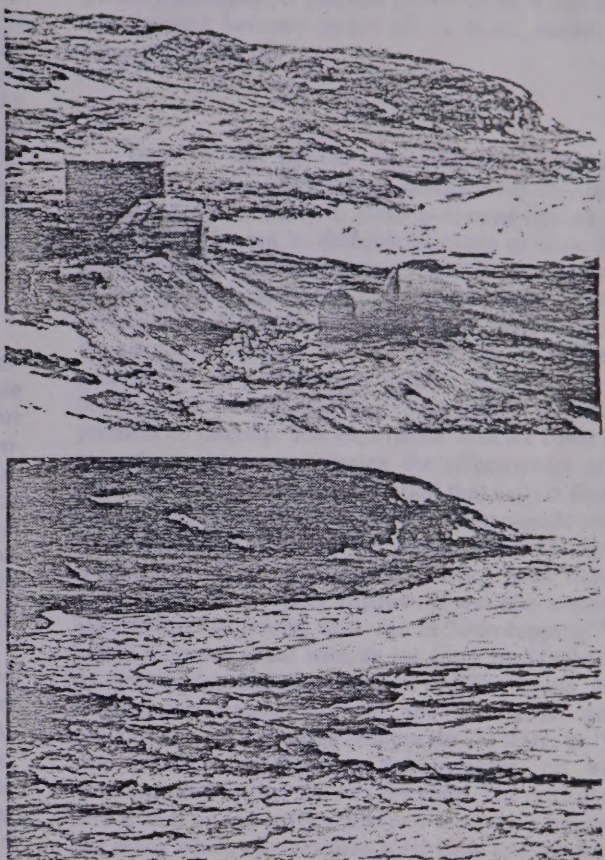

Figure 3: The tank farm at Deception Bay, Quebec after the slide of early June, 1970. (a) The six tanks in the farm; that tank on the far right was reported to have been nearly empty. (b) Area about the tank on the intertidal zone after cleanup. Note that the burn has "opened up" the ice of the intertidal zone in front of the slide. (c) The start of the burn within the intertidal zone of the slide.

onto the sea ice included the observation that evaporation was occurring and that, as the exposure and surface area would be very much increased, the rate and quantity evaporated would increase. I concluded that this would have been an effective method of cleanup of that oil on the ice surface. However, there were other considerations, including the imminent breakup of the ice cover and the requirement to burn at least part of the oil, i.e.,that portion mentioned above which remained in the intertidal zone of the slide area out of reach of the pumps. Therefore, it was decided to effect an immediate cleanup by burning.

Oil under Ice Cover

It was a tentative conclusion that , away from intertidal zones and lagoons, oil did not accumulate under an ice cover, at least not under the uniformly flat ice without ridges which was generally experienced. It was also concluded that unoiled shores downwind of an area of containment remained free of oil. The initial consideration was that the ice cover was simply serving as a very effective "boom." Subsequently, it seemed that oil may be transported under an ice cover, but in particulate form within the water column, and hence not generally available to oil a shore.

On the other hand, many of the small lagoons around Chedabucto Bay became ice covered and a number contained oil. The topography of some lagoons was such that they were relatively strongly coupled to the sea outside. Nevertheless,most of the oil in them remained as long as the ice cover remained, i.e., the ice and oil were generally dispersed from the lagoon at the same time (Figure 1d). In certain other lagoons (containing oil) with little coupling to the sea, the oil did not move about under the ice cover, i.e., it was generally observed in the same location and pattern. Subsequently, the ice cover was dispersed by melting and the oil was then moved about by the wind to oil the internal shores of the lagoon.

To some extent this experience might have been anticipated. The ice cover removes the influence of wind and the Bunker C fuel oil should have little tendency to spread at water temperatures near freezing[10], especially if it contained water[2]. As well, and with regard to the lagoon experience generally, it was not known to what extent the oil was trapped between layers of ice there, except that in some places it was[2].

That ice can provide very effecitve containment is evident. It is also evident that containment cannot always be exploited in recovery or cleanup as some fule oil, Bunker C for example, can be difficult to pump or burn. There is some evidence that both these difficulties may be overcome so that given containment it should be possible to clean up any spilled fuel oil. On the other hand, there has yet to be an adequate solution to the problem of containment generally[10], at least in areas without an ice cover, so that provision of containment has continued to be the central problem of cleanup. The experience with ice cover and the general conclusion concerning the effectiveness of an ice cover carried with it the implication that certain features of an ice cover might be arranged for in a man-made structure. It was realized that an ice cover achieved significant containment of oil on the water surface even though the cover could be relatively shallow. It was also realized that most failures of booms were due to "over-topping"[11]. The failure does not occur with an ice cover mainly because of the greater expanse relative to an ordinary boom, but also because the leading edge of the ice barrier generally contains broken ice which reduces the sea state, or "chop", and hence, over-topping. Subsequently, oil becomes contained and further reduces the chop. The critical feature here is that an ice cover achieves a separation between the line along which containment is achieved and the line along which the wave energy acts. In most ordinary booms the two coincide.

There are a number of ways by which the separation might be achieved including the use of an air bubble barrier to reduce the wind waves or by the addition of material to simulate a field of broken ice. Were either of these measures effective it might then be possible to look to a redesign of the main barrier within the concept of a horizontal, rather than vertical, array and so achieve a containment approaching that of an ice cover. It is conceivable that such an array would be inherently stable and flexible.

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